

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
13 March 2003 (13.03.2003)

PCT

(10) International Publication Number  
**WO 03/021730 A2**

(51) International Patent Classification<sup>7</sup>: **H01S 3/067**

(21) International Application Number: PCT/US02/25240

(22) International Filing Date: 7 August 2002 (07.08.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
09/924,957 7 August 2001 (07.08.2001) US

(71) Applicant (*for all designated States except US*): **HRL LABORATORIES, LLC** [US/US]; 3011 Malibu Canyon Road, Malibu, CA 90265 (US).

(72) Inventors; and

(75) Inventors/Applicants (*for US only*): **MINDEN, Monica** [US/US]; 847 Malibu Meadows Drive, Calabasas, CA 91302 (US). **STARODUBOV, Dmitry** [US/US]; 427 Westminster Ave., Los Angeles, CA 90020 (US).

(74) Agent: **TOPE-MCKAY, Cary, R.**; Tope-McKay & Associates, 23852 Pacific Coast Highway #311, Malibu, CA 90265 (US).

(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

**Published:**

— *without international search report and to be republished upon receipt of that report*

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

(54) Title: SINGLE POLARIZATION FIBER LASER

(57) Abstract: A method and apparatus for generating single polarization fiber laser output are disclosed. A Bragg grating is non-destructively fabricated within the fiber to introduce differential loss between the two polarizations of the laser output. Curvature at the grating site into a tight loop further increases the differential loss between the available polarizations.



**WO 03/021730 A2**

## SINGLE POLARIZATION FIBER LASER

### FIELD OF THE INVENTION

The present invention relates to a method and apparatus for obtaining electromagnetic  
5 radiation having a single polarization from a fiber laser.

### BACKGROUND OF THE INVENTION

Fiber optic lasers naturally oscillate in both available electromagnetic radiation  
polarizations. However, single polarization laser output is required in a large proportion  
10 of laser systems. Components that use polarized electromagnetic radiation include  
heterodyne detectors, most modulators, frequency doublers and shifters, and many  
amplifiers. Thus, the ability to generate single polarization fiber laser output is critical  
to most applications for fiber laser technology, including but certainly not limited to  
laser communications, laser radar for military and automotive applications, and active  
15 imaging systems. However, presently, no suitable method exists for polarizing fiber  
laser output that does not incur splicing losses between dissimilar fibers or require high-  
risk, labor-intensive fabrication steps

A number of techniques have been proposed and/or demonstrated for making a fiber  
20 laser oscillate in only one polarization. One such method requires splicing single  
polarization fiber onto the doped fiber. However, presently available single polarization  
fibers do not match the parameters of the doped fibers used for the laser gain; numerical  
aperture and core diameter, for example, are considerably different. Thus, the internal  
splice between the dissimilar fibers creates undesired loss.

25 In another technique the doped fiber is polished to its core and then metallic or  
waveguided loss of one of the polarizations is introduced into the fiber. However, this  
approach is labor-intensive and not cost-effective, and such techniques present a high  
risk of breaking the fiber laser.

30 Another proposed technique, though never successfully demonstrated, is to use the  
natural birefringence of a fiber grating by using two fiber segments spliced back

together after rotating one segment by 90°. However, this proposed technique is labor-intensive, is not cost-effective, and presents a high risk of fiber breakage.

### **SUMMARY OF THE INVENTION**

5 The present invention provides a method and apparatus for achieving single polarization output from a fiber laser that is low cost, comparatively simple, and presents minimal risk to the doped fiber. More specifically, the present invention provides a method and apparatus for generating single polarization fiber output by which a tightly looped fiber grating reflector is formed within the fiber laser itself. As noted above, a fiber grating  
10 has natural birefringence. This birefringence creates a differential loss between the two available polarizations. The present invention permits formation of this grating within a single fiber, and thus no splicing between components is required. The differential loss between the polarizations is further accentuated by tight looping of the fiber at the grating site. A modified technique is utilized for writing the Bragg grating within the  
15 fiber which, unlike currently used procedures, does not require the step of stripping the outer coating and the step of exposing the fiber to high intensity pulsed ultraviolet light, both of which mechanically weaken the fiber. Thus, upon formation of the grating, a loop can be created in the fiber without significant risk of breakage.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

20 **FIG. 1** illustrates the effects of creating a Bragg grating in a fiber laser and introducing a tight curve at the grating site on the polarization of the laser output.

**FIG. 2** depicts a non-destructive method for creating a Bragg grating in a fiber laser in  
25 order to polarize the laser output.

**FIG. 3** depicts the utilization of the looped polarizer according to the present invention in a fiber laser.

### **DETAILED DESCRIPTION OF THE INVENTION**

30 The present invention is useful for providing a method and apparatus for generating single polarization laser output from a fiber optic laser. The following description is

presented to enable one of ordinary skill in the art to make and use the invention, which may be incorporated in the context of a variety of applications. Various modifications to the preferred embodiment, as well as a variety of uses in different applications will be readily apparent to those skilled in the art. Notably, the general principles defined  
5 herein may be applied to other embodiments; thus, the present invention is not intended to be limited to the embodiments shown, but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

In the present invention, the natural birefringence of the Bragg grating within the fiber  
10 laser serves to create a differential loss between the two polarizations of the laser output. In a preferred embodiment of this invention, the fiber laser is curved into a tight loop at the position of the grating. Tight curvature at the grating site serves to increase the differential loss between the two polarizations. **FIG. 1** illustrates the affect of including a looped grating on the polarization of the laser output. Under ideal  
15 conditions, the natural output **100** of the fiber laser is converted essentially completely to a singularly polarized output **102** using a looped Bragg grating **104** according to the present invention.

The present invention takes advantage of a non-destructive technique for writing Bragg  
20 gratings within fiber lasers. Current procedures for writing gratings within fibers require first mechanically stripping the outer coating from the fiber followed by exposure to high power, pulsed far ultraviolet light (~244 nm). In a preferred embodiment of the present invention, the fiber is exposed instead to light in the 330 nm range. In this wavelength range, the polymer coating of the fiber is transparent and thus  
25 can remain intact. Furthermore, exposure at this wavelength takes advantage of the photosensitivity window of the fiber core, which is centered at 330 nm.

An example of a method for polarizing the output from a fiber laser according to the present invention is shown in **FIG. 2**. In this preferred embodiment of the present  
30 invention, Bragg gratings are fabricated in a neodymium-doped fiber **200** with ~20 mole percent germanium oxide in the core using the 334-nm line of a continuous wave argon laser **202**. Laser writing power is 50-200 mW. The laser beam **204** is expanded by a

cylindrical lens **206** to approximately 1.5 cm, and a second cylindrical lens **208** with focal length  $\sim 3$  cm focuses the beam onto the fiber core. A phase mask **210** with period  $\sim 730$  nm is placed in front of the fiber to impress a grating into the fiber core with a Bragg resonance at  $\sim 1060$  nm. A thin (200-micron) glass slide **212** is placed between  
5 the fiber and the phase mask to protect the phase mask surface from possible debris from the polymer coating. As monitored using a halogen lamp light source and an optical spectrum analyzer, gratings having 10% Bragg intensity reflection can be obtained in 20 seconds to 2 minutes. The resultant grating can then be curved at the site of the grating to introduce differential loss between the available polarizations.

10

An example of the utilization of the looped polarizer of the present invention is illustrated in **FIG. 3**. In this example, the Bragg grating **300** has 15% reflectivity and is written at one end of a 3 meter long neodymium fiber laser **302**, and a 4 % reflector **304** is positioned at the opposite end of the fiber. The laser system is coupled to a pump **306**  
15 through a coupler **308** at the same end of the fiber as the grating. In the present example, formation of a loop of approximately 1/4" diameter at the grating site completely suppresses lasing in one polarization while maintaining it in the other as measured at the output site **310**.

**CLAIMS**

What is claimed is:

1. A method for generating single polarization output from a fiber laser comprising the steps of using a non-destructive technique to fabricate a Bragg grating within  
5 the fiber laser and forming the fiber laser at the grating position into a tight curve.
2. A method for generating single polarization output from a fiber laser as set forth in claim 1, wherein the fiber laser has a surface and the non-destructive  
10 technique for fabricating the grating comprises the steps of positioning a phase mask parallel to a length of the surface of the fiber laser and irradiating the phase mask and fiber laser with electromagnetic radiation.
3. A method for generating single polarization output from a fiber laser as set forth  
15 in claim 2, wherein the phase mask and fiber laser are irradiated with 334 nm electromagnetic radiation from a continuous wave argon laser.
4. A method for generating single polarization output from a fiber laser as set forth in claim 3, wherein the electromagnetic radiation from the argon laser is  
20 conditioned by at least one lens prior to irradiating the mask and fiber laser.
5. A method for generating single polarization output from a fiber laser as set forth in claim 2, wherein a glass slide is placed between the surface of the fiber laser and the phase mask during fabrication of the grating to protect the phase mask  
25 from debris from the surface of the fiber laser.
6. A method for generating single polarization output from a fiber laser as set forth in claim 1, wherein the tight curve formed at the grating position is a complete  
30 loop in the fiber laser.

7. A method for generating a single polarization output from a fiber laser as set forth in claim 1, wherein the fiber laser is a neodymium (Nd) doped fiber.
8. A method for generating single polarization output from a fiber laser as set forth in claim 1, wherein the irradiating step utilizes electromagnetic radiation between 320 nm and 340 nm.
9. An apparatus for generating single polarization output from a fiber laser comprising a Bragg grating fabricated within the fiber laser using a non-destructive technique and further comprising a tight curve formed in the fiber laser at the grating position.
10. An apparatus for generating single polarization output from a fiber laser as set forth in claim 9, wherein said fiber laser has a surface and said Bragg grating is fabricated by positioning a phase mask parallel to a length of the surface of the fiber laser and irradiating the phase mask and fiber laser with electromagnetic radiation.
11. An apparatus for generating single polarization output from a fiber laser as set forth in claim 10, wherein the grating is fabricated by irradiating the mask and fiber laser with 334 nm electromagnetic radiation from a continuous wave argon laser.
12. An apparatus for generating single polarization output from a fiber laser as set forth in claim 11, wherein the 334 nm electromagnetic radiation is conditioned by at least one lens prior to irradiating the mask and fiber laser.
13. An apparatus for generating single polarization output from a fiber laser as set forth in claim 10, wherein a glass slide is placed between the surface of the fiber

laser and the phase mask during fabrication of the grating to protect the phase mask from debris from the surface of the fiber laser.

5 14. An apparatus for generating single polarization output from a fiber laser as set forth in claim 9, wherein the tight curve formed at the grating position is a complete loop in the fiber laser.

10 15. An apparatus for generating single polarization output from a fiber laser as set forth in claim 9, wherein the fiber laser is a neodymium (Nd) doped fiber.

16. An apparatus for generating single polarization output from a fiber laser as set forth in claim 9, wherein the fiber laser operates with electromagnetic radiation between 320 nm and 340 nm.



1/3

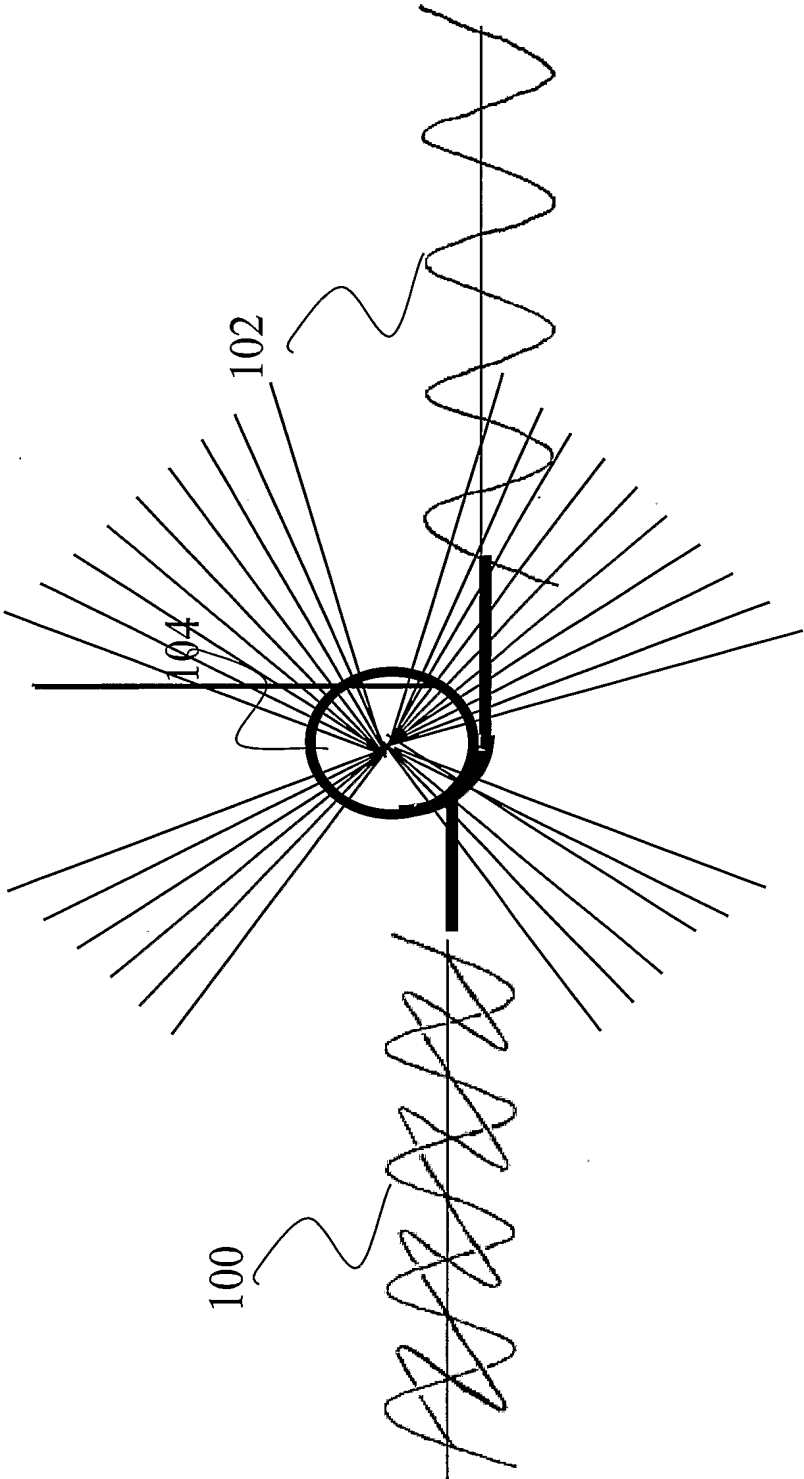


FIG. 1

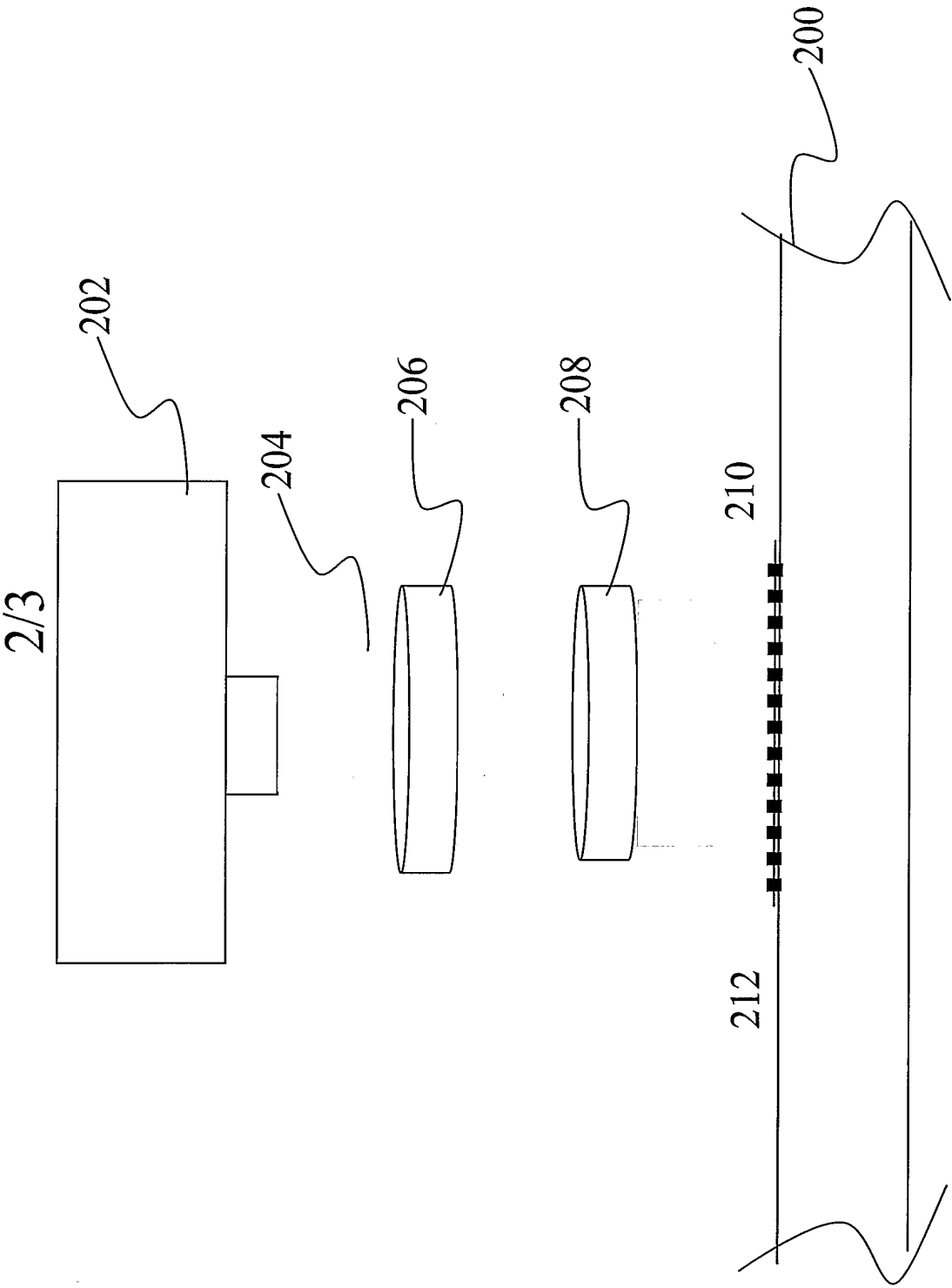


FIG. 2

3/3

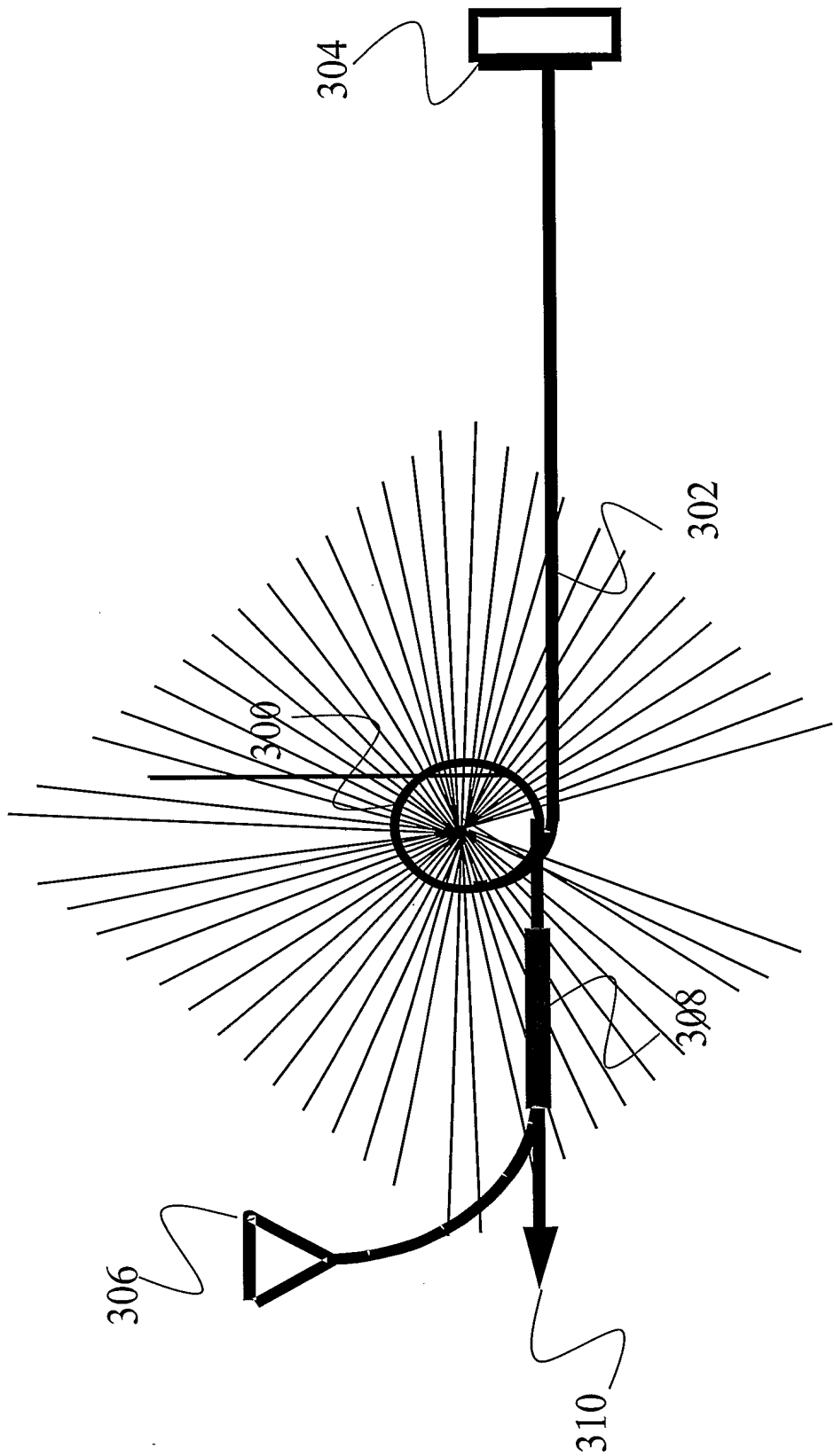


FIG. 3